Tag: E-2223/2224
Line 2 PES Reactor Jacket Cooler
Project # 58-CG87-30
Nova Chemicals
Drawing # D-6-107647
PO # 58CG8760P110007
Ì »®¿´ýÌ Õéêî ú Ì Õéêî
Ð@¶½ýï éçëï

TRANTER® A DOVER COMPANY
TRANTER PHE, Inc.
P.O. Box 2289 Wichita Falls, Texas

Shop Order No.: 107647-1

File: 107647_uxp060u_z1ubc.mcd

Model: UXP-060-M-6-UP-106, Seismic per Uniform Bldg Code 1997, Zone 1, Section 1632 Table 16-I & Section 1615 Table 16-F, 90 MPH

Check unit full of water. See page 6 for unit load diagram

$Sa := 20000 \cdot psi$ Allowable Stress

$Wu := 3964 \cdot lbf$ Unit Weight

$Wp := 1001 \cdot lbf$ Plate Weight

$Ww := 660 \cdot lbf$ Water Weight

$hr := \frac{L}{12}$

$ap := 1.0$ $Ip := 1.0$ $z := .30$

$hx := \frac{L1}{12}$

$Ca := .44$ $Rp := 3.0$ $Na := 1.5$

$T := 2.375 \cdot in$ Frame Thickness

$L := 73.81 \cdot in$

$L1 := 38.19 \cdot in$ Center of Gravity

$L2 := 11.13 \cdot in$ Center of Gravity

$L3 := 66.56 \cdot in$

$L4 := 65.63 \cdot in$ Guide Bar

$La := 17.11 \cdot in$ Plate Pack

$L5 := 13.50 \cdot in$ $L7 := 9.27 \cdot in$

$L6 := 56.61 \cdot in$ $L8 := L6 + L7$

$C_e := 1.06$ $I_i := 1.0$

$C_q := 1.31$ $q_s := 20.8 \cdot \frac{lbf}{ft^2}$

$W := Wu + Wp + Ww$ $W = 5625.00\, lbf$

$$Fh := \frac{ap \cdot Ip \cdot Ca \cdot Na}{Rp} \cdot W \cdot \left(1 + 3 \cdot \frac{hx}{hr}\right)$$ Due to earthquake

$Fh = 3158.4\, lbf$

Check Upper Guide Bar. See page 6 for unit load diagram.

$W1 := Wp + Ww$ $W1 = 1661.0\, lbf$

$Fv2 := \frac{La \cdot W1}{2 \cdot L4}$ $Fv2 = 216.5\, lbf$ $Fv1 := W1 - Fv2$ $Fv1 = 1444.5\, lbf$

$Mmax := \frac{Fv1^2 \cdot La}{2 \cdot W1}$ $Mmax = 10746.74\, lbf \cdot in$

Guide Bar: 4.65" Solid Round Bar

$I := 22.95 \cdot in^4$ $C := 2.325 \cdot in$ $Fty := 36000 \cdot psi$

$fb := \frac{Mmax \cdot C}{I}$ $fb = 1088.72\, psi$

$Fb := \frac{2}{3} \cdot Fty$ $Fb = 24000.00\, psi$ $Fb \le fb$ $MS := \frac{Fb}{fb} - 1$ $MS = 21.04$

JACOBS ENGINEERING GROUP - CENTRAL REGION
PROJECT NO. CG87 P.O. NO. P11-0007 SERIAL NO. 7-0
SIGNATURE/DATE [signature] 5/2/05 ITEM NO. E-2223, E2224
SUSPENSE DATE 5-5-05
☒ A NO COMMENTS
☐ B COMMENTS NOTED – REVISE, RESUBMIT, PROCEED WITH FABRICATION
☐ C UNACCEPTABLE – DO NOT PROCEED WITH FABRICATION
☐ R FOR INFORMATION ONLY
Review of this drawing by Jacobs Engineering Group does not relieve the supplier of his responsibility to supply the materials in accordance with the procurement documents.

Check Lateral Analysis inTransverse Direction, Check Rear Support Post, 10"x 45#/FT Structural WF Beam Column, See Page 7 for Rear Support Post Load Diagram.

$Iy := 53.4 \cdot in^4$ $Sy := 13.3 \cdot in^3$ $E := 29.0 \cdot 10^6 \cdot psi$

$R1 := Fh \cdot \frac{L1}{L3}$ $R1 = 1812.18\ lbf$ $t := 1.0 \cdot in$

$R2 := Fh - R1$ $R2 = 1346.20\ lbf$

$Mmax := R1 \cdot (L3 - t)$

$Mmax = 118806.47\ lbf \cdot in$

$fb1 := \frac{Mmax}{Sy}$ $\Delta := \frac{R1 \cdot L3^3}{3 \cdot E \cdot Iy}$ $\Delta = 0.12\ in$ GOOD

$fb1 = 8932.82\ psi$

$Fty1 := 36000 \cdot psi$

$Fb := \frac{2}{3} \cdot Fty1$

$Fb = 24000.00\ psi$ $Fb \le fb1$ $MS := \frac{Fb}{fb1} - 1$ $MS = 1.69$

Check Anchorage. See Page 7 for Base Plate Diagram

$A := 12.0 \cdot in$ $B := 15.0 \cdot in$ $N := 4$ $e := 2.0 \cdot in$

Tension per Bolt $Ts := \frac{Mmax}{A \cdot 2}$ $Ts = 4950.27\ lbf$

Shear per Bolt $Ss := \frac{Fh}{N}$ $Ss = 789.60\ lbf$

Check Base Plate Thickness. $g := 1.33$ Short Term Seismic Increase

$Sx := \frac{Ts \cdot 2 \cdot e}{Fty1 \cdot .75 \cdot g}$ $Sx = 0.55\ in^3$

$tb := \left(\frac{6 \cdot Sx}{B}\right)^{.5}$ $tb = 0.47\ in$ Minimum

Provide 15" X 15" X 0.75" Thick Base Plate. Anchor and Footing by Others.

Check Lateral Analysis in Longitudinal Direction.

$Mo := Fh \cdot L2$

$Mo = 35152.80\,lbf \cdot in$

$Mr := (Wu + Wp) \cdot \frac{L1}{2}$

$Mr = 94806.68\,lbf \cdot in$ $\qquad Mr \geq 1.5 \cdot Mo \qquad 1.5 \cdot Mo = 52729.20\,lbf \cdot in$

Check Stationary Frame. See Page 7 for Load Diagram.

Check Moment @ Bottom Nozzle Due to Seismic Load.

$w := \frac{Fh}{L6} \qquad R3 := \frac{w \cdot L6}{2 \cdot L8} \cdot [(2 \cdot L8) - L6] \qquad R3 = 1801.40\,lbf$

$R4 := \frac{w \cdot L6^2}{2 \cdot L8} \qquad R4 = 1356.98\,lbf$

$Ms := R3 \cdot (L8 - L5) - w \cdot \frac{(L8 - L5)^2}{(2)} \qquad Ms = 17820.13\,lbf \cdot in$

Check Moment @ Bottom Nozzle Due to Operating Pressure. See Attached Frame Calculation Page 3 for Moment (Mh).

$Mh := 62423.5654 \cdot lbf \cdot in$

Total Moment @ Bottom Nozzle:

$Mt := Ms + Mh \qquad Mt = 80243.69\,lbf \cdot in$

$b := 29.75 \cdot in$ Width of Frame

$dn := 8.6875 \cdot in$ Nozzle Diameter

$S := \frac{(b - dn \cdot 2) \cdot T^2}{6} \qquad S = 11.63\,in^3$

$fb2 := \frac{Mt}{S} \qquad fb2 = 6897.47\,psi$

$Fb1 := 1.5 \cdot Sa \qquad Fb1 = 30000.00\,psi$

$MS := \frac{Fb1}{fb2} - 1 \qquad MS = 3.35$

"Fh" May Act in any Direction Within the Horizontal Plane. Check the Stationary Frame with "Fh" Acting in the Side Direction. Assume the Entire Load of "Fh" is Carried in Torsion by the Stationary Frame.

$A_{wind} := \frac{L \cdot (La + T \cdot 2)}{144 \cdot \frac{in^2}{ft^2}}$ $\quad A_{wind} = 11.20\,ft^2$ $\quad Fhw := I_1 \cdot C_e \cdot C_q \cdot q_s \cdot A_{wind}$

$Fhw = 323.63\,lbf$ Due to wind

$Fhw < Fh$ Use earthquake Load "Fh" for Design

$\tau := Fh \cdot L2$ $\quad a := \frac{b}{2}$ $\quad T1 := \frac{T}{2}$

$\tau = 35152.80\,lbf \cdot in$ Ref. "ROARK" 4th Edition Page 194, Case 4

$\sigma := \frac{\tau \cdot (3 \cdot a + 1.8 \cdot T1)}{8 \cdot a^2 \cdot T1^2}$ $\quad \sigma = 658.55\,psi$

$Fb3 := .4 \cdot Fty$ $\quad Fb3 = 14400.00\,psi$ $\quad MS := \frac{Fb3}{\sigma} - 1$ $\quad MS = 20.87$

Check anchorage for "S" frame base plate: See Page 8 for base plate diagram

$J := 12.0 \cdot in$ $\quad h := 2.25 \cdot in$ $\quad N := 8$ $\quad g := 7.0 \cdot in$ $\quad K := 10.0 \cdot in$

$N_1 := \frac{N}{2}$ Number of bolt reactions $\quad Base\_Plates := 2$

Tension $\quad Tf := \frac{\tau}{N_1 \cdot g}$ $\quad Tf = 1255.46\,lbf$ per bolt

Shear $\quad Sf := \frac{Fh}{N}$ $\quad Sf = 394.80\,lbf$ per bolt

Check base plate thickness:.

$Z_T = \left(\frac{J \cdot t_r^2}{6}\right) \cdot Base\_Plates$ $\quad M = N_1 \cdot Tn \cdot h$ $\quad \sigma a = \frac{M}{Z_T}$

Solve for tr

$t_r := \left(\frac{18 \cdot Tf \cdot h}{J \cdot Fb}\right)^{\frac{1}{2}}$ $\quad t_r = 0.42\,in$ minimum

Provide (2) 10" X 12" X 3/4" base plate. Anchor and footing by others:

Check welding for "S" frame base plate: $\quad Ft := 70000 \cdot psi$

$M_b := \frac{\tau}{2}$ $\quad \sigma_{aw} := .3 \cdot Ft \cdot .707$ $\quad \sigma_{aw} = 14847.00\,psi$ Weld allowable

Check Welding of Base Plate con't.

$Laa := J$ Length of weld line h1 = min. required leg of weld

$$\sigma_w = \frac{1.414 \cdot M_b}{h_1 \cdot Laa \cdot (T + h_1)}$$

SOLVE FOR h1

$$h_1 := \frac{-(\sigma_{aw} \cdot Laa \cdot T) + \left[(\sigma_{aw} \cdot Laa \cdot T)^2 + (4 \cdot 1.414 \cdot \sigma_{aw} \cdot Laa \cdot M_b)\right]^{\frac{1}{2}}}{2 \cdot \sigma_{aw} \cdot Laa}$$

$h_1 = 0.06\,in$ minimum, use 3/8" fillet weld

Check bolting for combined tension and shear in rear support:

Allowable Bolt Load for ASTM A325 bolts per Latest Edition AISC Table J3.2 (Section 5-73) and (Section 4.30). Area for tension is
"Tensile Stress Area" and area for shear is "Gross Area".

(A) Check 3/4" Diameter Hex Bolts:

$Ten\_area := 0.302 \cdot in^2$

$Shear\_area := 0.4418 \cdot in^2$

$Shear_{allowable} := 7510 \cdot lbf$

$f_{ut} := 120000 \cdot psi$

$Ts = 4950.27\,lbf$

$Ss = 789.60\,lbf$

$Tension_{allowable} := 19400 \cdot lbf$

For combined tension and shear the following shall be met:

$\phi := .65$

$P_{SS} := .9 \cdot Ten\_area \cdot f_{ut}$ $P_{SS} = 32616.00\,lbf$ $V_{SS} := .75 \cdot Shear\_area \cdot f_{ut}$ $V_{SS} = 39762.00\,lbf$

$$T_1 = \frac{1}{\phi} \cdot \left[\left(\frac{Ts}{Tension_{allowable}}\right) \le 1.0\right]$$

$$S_2 = \frac{1}{\phi} \cdot \left[\left(\frac{Ss}{Shear_{allowable}}\right) \le 1.0\right]$$

$$T_{1\_S.2} = \frac{1}{\phi} \cdot \left[\left(\frac{Ts}{Tension_{allowable}}\right)^{\frac{5}{3}} + \left(\frac{Ss}{Shear_{allowable}}\right)^{\frac{5}{3}}\right] \le 1.0$$

$$S_3 = \left[\left(\frac{Ts}{P_{SS}}\right)^2 + \left(\frac{Ss}{V_{SS}}\right)^2 \le 1.0\right]$$

$$T_1 := \frac{1}{\phi}\cdot\left(\frac{Ts}{Tension_{allowable}}\right) \qquad T_1 = 0.39 \qquad T_1 \le 1.0$$

$$S_2 := \frac{1}{\phi}\cdot\left(\frac{Ss}{Shear_{allowable}}\right) \qquad S_2 = 0.16 \qquad S_2 \le 1.0$$

$$T_{1\_S.2} := \frac{1}{\phi}\cdot\left[\left(\frac{Ts}{Tension_{allowable}}\right)^{\frac{5}{3}} + \left(\frac{Ss}{Shear_{allowable}}\right)^{\frac{5}{3}}\right] \qquad T_{1\_S.2} = 0.19 \qquad T_{1\_S.2} \le 1.0$$

$$S_3 := \left(\frac{Ts}{P_{SS}}\right)^2 + \left(\frac{Ss}{V_{SS}}\right)^2 \qquad S_3 = 0.02 \qquad S_3 \le 1.0$$

Check bolting for combined tension and shear in "S" frame base plates:

Allowable Bolt Load for ASTM A325 bolts per Latest Edition AISC Table J3.2 (Section 5-73) and (Section 4.30). Area for tension is "Tensile Stress Area" and area for shear is "Gross Area".

(A) Check 3/4" Diameter Hex Bolts:

$Ten\_area := 0.302\cdot in^2$ $\qquad$ $Shear\_area := 0.4418\cdot in^2$

$Tf = 1255.46\ lbf$

$Shear_{allowable} := 7510\cdot lbf$ $\qquad$ $f_{ut} := 120000\cdot psi$ $\qquad$ $Sf = 394.80\ lbf$

$Tension_{allowable} := 19400\cdot lbf$

For combined tension and shear the following shall be met:

$P_{SS} := .9\cdot Ten\_area\cdot f_{ut}$ $\qquad$ $P_{SS} = 32616.00\ lbf$ $\qquad$ $V_{SS} := .75\cdot Shear\_area\cdot f_{ut}$ $\qquad$ $V_{SS} = 39762.00\ lbf$

$$T_1 = \frac{1}{\phi}\cdot\left[\left(\frac{Tf}{Tension_{allowable}}\right) \le 1.0\right] \qquad S_2 = \frac{1}{\phi}\cdot\left[\left(\frac{Sf}{Shear_{allowable}}\right) \le 1.0\right]$$

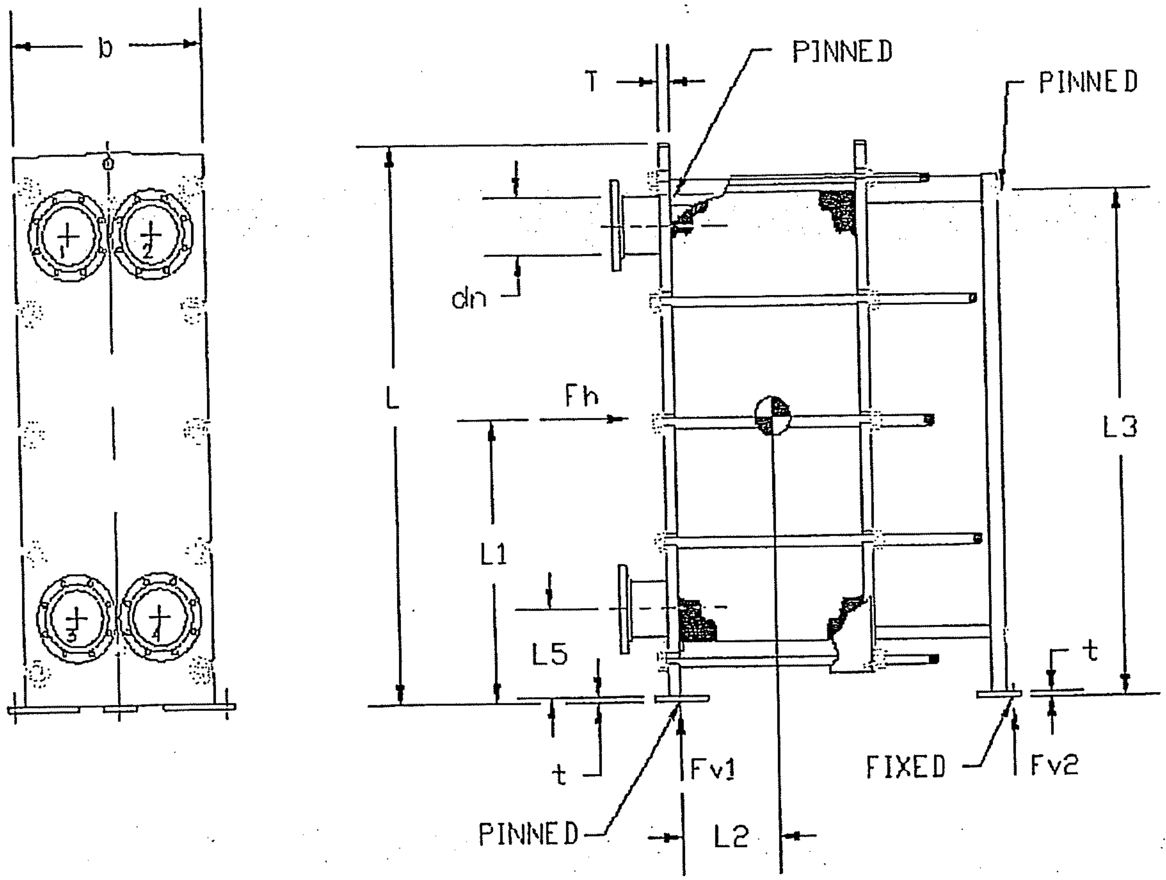
$$T_{1\_S.2} = \frac{1}{\phi}\cdot\left[\left(\frac{Tf}{Tension_{allowable}}\right)^{\frac{5}{3}} + \left(\frac{Sf}{Shear_{allowable}}\right)^{\frac{5}{3}}\right] \le 1.0 \qquad S_3 = \left[\left(\frac{Tf}{P_{SS}}\right)^2 + \left(\frac{Sf}{V_{SS}}\right)^2 \le 1.0\right]$$

$$T_1 := \frac{1}{\phi}\cdot\left(\frac{Tf}{Tension_{allowable}}\right) \qquad T_1 = 0.10 \qquad T_1 \le 1.0$$

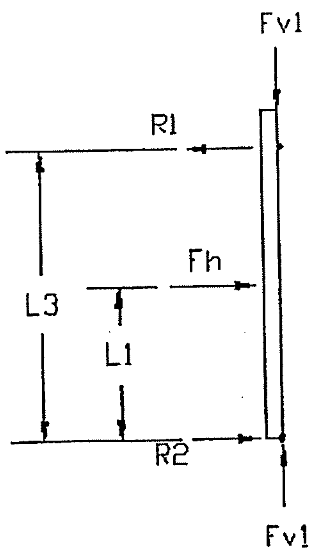
$$S_2 := \frac{1}{\phi}\cdot\left(\frac{Sf}{Shear_{allowable}}\right) \qquad S_2 = 0.08 \qquad S_2 \le 1.0$$

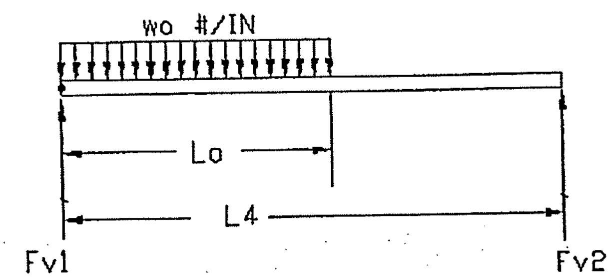
$$T_{1\_S.2} := \frac{1}{\phi}\cdot\left[\left(\frac{Tf}{Tension_{allowable}}\right)^{\frac{5}{3}} + \left(\frac{Sf}{Shear_{allowable}}\right)^{\frac{5}{3}}\right] \qquad T_{1\_S.2} = 0.03 \qquad T_{1\_S.2} \le 1.0$$

$$S_3 := \left(\frac{Tf}{P_{SS}}\right)^2 + \left(\frac{Sf}{V_{SS}}\right)^2 \qquad S_3 = 0.00 \qquad S_3 \le 1.0$$

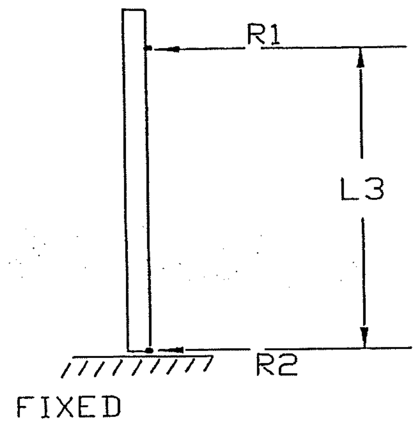


UNIT LOAD DIAGRAM

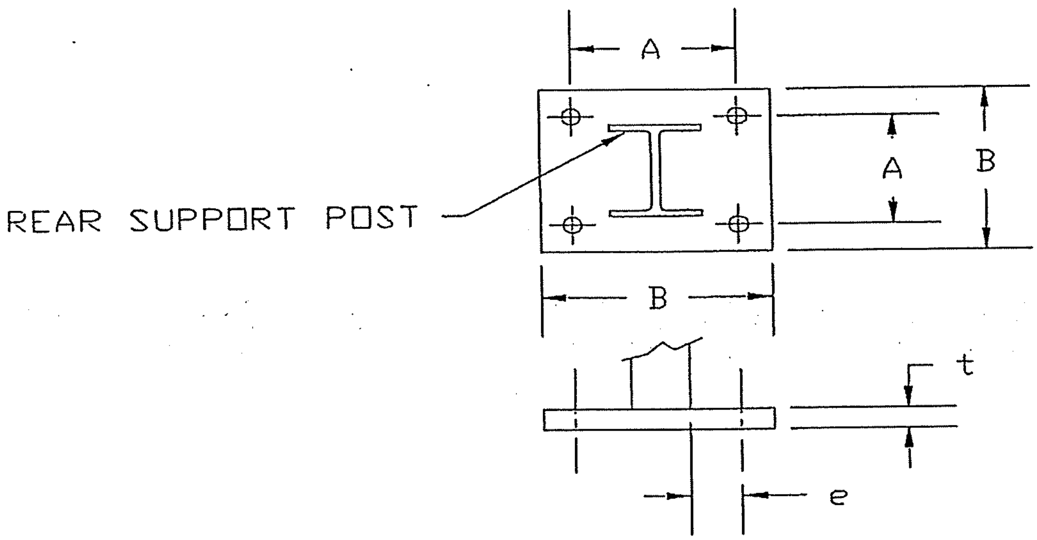




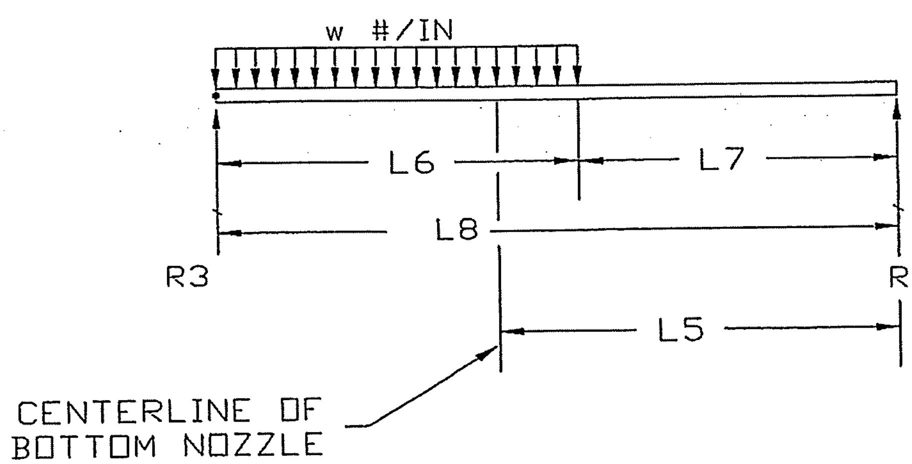
UPPER GUIDE BAR LOAD DIAGRAM



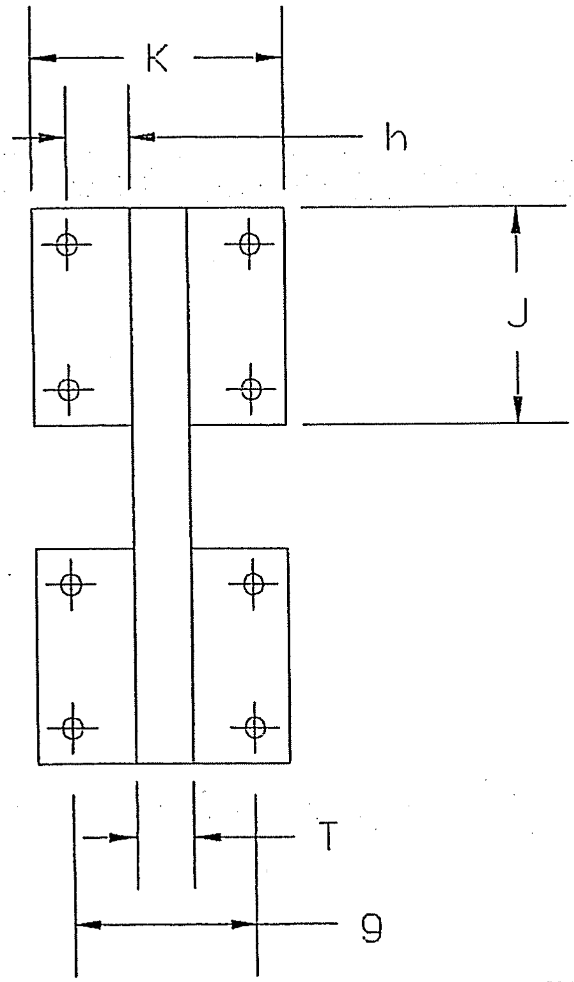
REAR SUPPORT POST LOAD DIAGRAM



REAR BASE PLATE DIAGRAM



STATIONARY FRAME LOAD DIAGRAM



STATIONARY FRAME BASE PLATE

BY: CLAUDE BOLES
CHECKED BY: JEFF MATHUR, P.E.
DATED: 04-25-2005

Tag: E-2223/2224
Line 2 PES Reactor Jacket Cooler
Project # 58-CG87-30
Nova Chemicals
Drawing # D-6-107647
PO # 58CG8760P110007

TRANTER® A DOVER COMPANY
THE heat transfer people
TRANTER PHE, Inc.
P.O. Box 2289 Wichita Falls, Texas

S/O: 107647-1

file: 107647_5uxp060u.mcd

MODEL: UXP-060-U FRAME WITH (10) 1 1/2" DIA. BOLTS

FRAME CALCULATION: Reference ASME Code Section V111 Div. 1, Para. U2(g) Latest edition and addenda. The frame thickness is calculated by the method of "Theorem of Three Moments".

(1) LOAD:

$P := 150.00 \frac{lbf}{in^2}$ (DESIGN PRESSURE) $L3 := 22.91 in$ $Lg1 := 56.61 in$ (PRESSURE AREA)

$A := L3 \cdot Lg1$ $A = 1296.9351 in^2$ $Gn := 8.47 in$ (GASKET PORT DIA.)

$Ws := 81.10 \frac{lbf}{in}$ (GASKET LOAD)

$Lg := [(L3 + Lg1) \cdot 2 + 2 \cdot \pi \cdot Gn]$ $Lg = 212.2586\ in$ (GASKET LENGTH)

$Wt := (P \cdot A) + (Ws \cdot Lg)$ $Wt = 211754.4358\ lbf$

(2) CALCULATION OF FRAME THICKNESS IN HORIZONTAL DIRECTION.

(a) VERTICAL BENDING MOMENTS. (SEE FIG. 1 FOR DRAWING OF FRAME AND FIG. 2 FOR VERTICAL BENDING MOMENT DIAGRAM.

$Wv := \left(\frac{Wt}{Lg1}\right)$ $La := 1.82 in$ $L1 := 15.0625 \cdot in$ $L5 := (Lg1 + 2 \cdot La)$ $L5 = 60.2500\ in$

$Wv = 3740.5836 \frac{lbf}{in}$ $L := \frac{(L5 - 2 \cdot L1)}{2}$ $L = 15.0625\ in$

$M1 := 0 \cdot lbf \cdot in$ $M5 := 0 \cdot lbf \cdot in$ The support is "Simple Support" .Hence No Moment is present.

$$M2 := \frac{-1}{56} \cdot Wv \cdot \frac{\left(7 \cdot L1^5 + 9 \cdot L \cdot L1^4 - 14 \cdot L1^3 \cdot La^2 - 18 \cdot L \cdot L1^2 \cdot La^2 + 3 \cdot L^3 \cdot L1^2 + 5 \cdot L^4 \cdot L1 + 7 \cdot L1 \cdot La^4 + 9 \cdot L \cdot La^4\right)}{\left[L1 \cdot \left(2 \cdot L \cdot L1 + L^2 + L1^2\right)\right]}$$

$M2 = -89170.68\ lbf \cdot in$

$$M3 := \frac{1}{14} \cdot Wv \cdot \frac{L1^4 - 2 \cdot L1^2 \cdot L^2 - 2 \cdot L1^2 \cdot La^2 - L^3 \cdot L1 + La^4}{L1 \cdot (L1 + L)}$$ $M3 = -61497.10\ lbf \cdot in$

$$M4 := \frac{-1}{56} \cdot Wv \cdot \frac{9 \cdot L1^5 - 18 \cdot L1^3 \cdot La^2 + 9 \cdot L1 \cdot La^4 + 5 \cdot L^3 \cdot L1^2 + 7 \cdot L \cdot L1^4 - 14 \cdot L \cdot L1^2 \cdot La^2 + 7 \cdot L \cdot La^4 + 7 \cdot L^4 \cdot L1 - 4 \cdot L1^3 \cdot L^2}{L1 \cdot \left(2 \cdot L \cdot L1 + L^2 + L1^2\right)}$$

$M4 = -89170.68\ lbf \cdot in$

(2) CALCULATION OF FRAME THICKNESS CONTINUED.

SHEAR FORCES AT THE SUPPORTS BASED ON THE MOMENTS CALCULATED ABOVE

SHEARING FORCE @ LEFT OF SUPPORT.

$$F1 := \frac{\left[-M1 + M2 + Wv\cdot\frac{(L1 - La)^2}{2}\right]}{L1}$$

$$F2 := \frac{\left[-M2 + M3 + Wv\cdot\frac{(L)^2}{2}\right]}{L}$$

F1 = 15854.6592 lbf

F2 = 30008.5204 lbf

$$F3 := \frac{\left(-M3 + M4 + Wv\cdot\frac{L^2}{2}\right)}{L}$$

$$F4 := \frac{\left[-M4 + M5 + Wv\cdot\left[\frac{(L1 - La)^2}{2}\right] + Wv\cdot La\cdot(L1 - La)\right]}{L1}$$

F3 = 26334.0196 lbf

F4 = 33680.0187 lbf

$$F5 := \frac{\left[-M4 - Wv\cdot\frac{(L1 - La)^2}{2}\right]}{L1}$$

F5 = −15854.6592 lbf

SHEARING FORCE @ RIGHT OF SUPPORT.

$F2a := -F4$ F2a = −33680.0187 lbf

$F3a := -F3$ F3a = −26334.0196 lbf

$F4a := -F2$ F4a = −30008.5204 lbf

Finding the Maximum Bending moment in between the support reactions.
Maximum Bending moment occurs at the point where the Shear force is "0"

<u>**Between R1 & R2**</u>

$xb := \frac{F1}{Wv} + La$ xb = 6.0586 in The distance of point of Max. Bending moment From Support R1

$M2a := F1\cdot xb - Wv\cdot\frac{(xb - La)^2}{2}$ Max. Bending Moment M2a = 62455.8812 lbf·in

Between R2 & R3

$xc := \frac{F2}{Wv}$ $\quad xc = 8.0224\,in$ $\quad$ The distance of point of Max. Bending moment From Support R2

$M3a := M2 + F2 \cdot xc - Wv \cdot \frac{xc^2}{2}$ $\quad$ Max. Bending Moment $\quad M3a = 31199.7471\,lbf \cdot in$

Between R3 & R4

$xd := \frac{F3}{Wv}$ $\quad xd = 7.0401\,in$ $\quad$ The distance of point of Max. Bending moment From Support R3

$M4a := M3 + F3 \cdot xd - Wv \cdot \frac{xd^2}{2}$ $\quad$ Max. Bending Moment $\quad M4a = 31199.7471\,lbf \cdot in$

Between R4 & R5

$xe := \frac{F4}{Wv}$ $\quad xe = 9.0039\,in$ $\quad$ The distance of point of Max. Bending moment From Support R4

$M5a := M4 + F4 \cdot xe - Wv \cdot \frac{xe^2}{2}$ $\quad$ Max. Bending Moment $\quad M5a = 62455.8812\,lbf \cdot in$

(b) HORIZONTAL BENDING MOMENT. (SEE FIG. 3 FOR DRAWING OF HORIZONTAL BENDING MOMENT DIAGRAM.)

$L4 := 26.18\,in$ $\quad L2 := \frac{L4 - L3}{2}$ $\quad L2 = 1.6350\,in$

$Wh := \frac{Wt}{L3}$

$Wh = 9242.8824\,\frac{lbf}{in}$

$Mhmax := .5 \cdot Wh \cdot \left(L2^2 - .25 \cdot L4^2\right)$ $\quad Rh := \frac{Wh \cdot L3}{L4} \cdot \left(L2 + \frac{L3}{2}\right)$

$Mhmax = -779521.02\,lbf \cdot in$ $\quad Rh = 105877.2179\,lbf$

(c) TOTAL STRESS. MATERIAL: SA516-70; ALLOWABLE = 20000 PSI

$Mvmax := M2$

$Sa := 20000 \frac{lbf}{in^2}$

$$Tp := \left[\left(\frac{6}{Sa}\right)\cdot\left[\left(\frac{Mvmax}{L4}\right)^2 + \left[\left(\frac{Mhmax}{L5}\right)^2\right]\right]^{.5}\right]^{.5}$$

$Tp = 2.0034\,in$ MINIMUM.

(3) CHECK TIGHTENING BOLT.

(a) REACTIONS UNDER VERTICAL DIRECTION.

$$R1 := \frac{\left[M2 + Wv\cdot\frac{(L1 - La)^2}{2}\right]}{L1}$$

$R2 := F1 - Wv\cdot(L1 - La) - F2$

$R2 = -63688.5391\,lbf$

$R1 = 15854.6592\,lbf$

$R3 := F2 - Wv\cdot L - F3$

$R4 := F3 - Wv\cdot L - F4$

$R4 = -63688.5391\,lbf$

$R3 = -52668.0393\,lbf$

$R5 := F4 - Wv\cdot(L1 - La)$

$R5 = -15854.6592\,lbf$

(b) CHECK MAXIMUM BOLT STRESS. MATERIAL: SA-193-B7
ALLOWABLE STRESS = 25000 PSI

$Rvmax := \frac{R2}{2}$ $Rvmax = -31844.2695\,lbf$

$Rhmax := \frac{Rh}{5}$ $Rhmax = 21175.4436\,lbf$

USE Rvmax FOR MAXIMUM BOLT LOAD.

$Dt := 1.3466\,in$ FOR 1 1/2" DIA. BOLT

$$Sb := \frac{Rvmax\cdot 4}{\pi\cdot Dt^2}$$

$Sb = -22359.6082 \frac{lbf}{in^2}$ < ALLOWABLE STRESS

(4) CHECK TIE-BOLT CUT-OUT AREA. (SEE FIG. 5 FOR DRAWING OF BOLT CUT-OUT AREA.)

MAX BENDING MOMENT IS AT M2

$Db := 1.5in$ $\quad$ $Cb := L4 - Db - .125in$ $\quad$ $Cb = 24.5550\,in$

$$Tb := \left(\frac{6\cdot|M2|}{Cb\cdot Sa}\right)^{.5}$$ $Tb = 1.0438\,in$ MINIMUM.

(5) CHECK REQUIRED THK. OF FRAME PLATE IN VIEW OF REINFORCEMENT AT NOZZLE HOLES

CHECK SHEAR AND MOMENT AT EACH POINT 1 THRU 5 AROUND THE NOZZLE OPENING ABOUT THE VERTICAL AXIS.

$d := 8.69in$ NOZZLE OPENING $\quad$ $B := 29.75in$ Width of Frame

$L6 := 14.19in$ $\quad$ $d2 := \frac{L3 - (L6 + d)}{2}$ $\quad$ $d2 = 0.015\,in$ $\quad$ $d3 := \frac{d}{4}$ $\quad$ $d3 = 2.1725\,in$

$L7 := B - 2\cdot d$ $\quad$ $L7 = 12.3700\,in$

Refer the Figure 1. Five (1 through 5) points are marked on the Nozzle hole periphery. At these 5 points the bending moment in Horizontal & Vertical direction is calculated.
Combining the maximum Horizontal & Vertical Bending moments, THE MINIMUM REQUIRED THK. AT NOZZLE CUT-OUT PERIPHERY is calculated.

DIMENSIONS USED (REFER FIG. 3)

$d1 := \frac{(L6 - d)}{2}$ CENTER OF FRAME PLATE TO EDGE OF NOZZLE HOLE (HORIZONTAL DIR.)

$d1 = 2.750\,in$

$d2 := \frac{L3 - (L6 + d)}{2}$ CENTER OF GASKET TO EDGE OF NOZZLE HOLE (HORIZONTAL DIR.)

$d2 = 0.0150\,in$

$d3 := \frac{d}{4}$ ONE FOURTH OF NOZZLE HOLE DIA. AT THIS DISTANCE, EACH POINT (IN HORIZONTAL DIRECTION) IS PLACED AROUND NOZZLE.

$d3 = 2.1725\,in$

(5)(a)BENDING MOMENTS IN HORIZONTAL DIRECTION AT 5 POINTS ABOUT PERIPHERY OF NOZZLE HOLE

Refer Fig. 3 for bending moment diagram & Fig. 6 below for the details of points around nozzle hole.

$$Mh1 := Rh\cdot(L2 + d2) - Wh\cdot\frac{d2^2}{2}$$ MOMENT AT Pt. 1

$Mh1 = 174696.3697\ lbf\cdot in$

$$Mh2 := Rh\cdot(L2 + d2 + d3) - Wh\cdot\frac{(d2 + d3)^2}{2}$$ MOMENT AT Pt. 2

$Mh2 = 382601.3472\ lbf\cdot in$

$$Mh3 := Rh\cdot(L2 + d2 + 2\cdot d3) - Wh\cdot\frac{(d2 + 2\cdot d3)^2}{2}$$ MOMENT AT Pt. 3

$Mh3 = 546882.1727\ lbf\cdot in$

$$Mh4 := Rh\cdot(L2 + d2 + 3\cdot d3) - Wh\cdot\frac{(d2 + 3\cdot d3)^2}{2}$$ MOMENT AT Pt. 4

$Mh4 = 667538.8462\ lbf\cdot in$

$$Mh5 := Rh\cdot(L2 + d2 + d) - Wh\cdot\frac{(d2 + d)^2}{2}$$ MOMENT AT Pt. 5

$Mh5 = 744571.3677\ lbf\cdot in$

Now , the Thickness required at Pt. 1 , "tv1" through Pt.5, "tv5" is determined . The bending moment at the highest thickness point will be considered for next step.

$Lv1 := L5 + Db$ $\quad Lv1 = 61.750\ in$

Lv1 is the width of frame plate considered for calculation of Moment Of Inertia . Refer the Following figure . Note that The width for Pt. 1 & Pt. 5 are same . This is true for Pt2. & Pt.4 . Also Note that for the Pt.2 & Pt.3 & Pt.4 , the width in consideration will be reduced by amount of 4 x dv2 , 4 x dv3 , 4 x dv2 respectively . This will increase the thickness requirement arond the Nozzle Hole . We need to calculate this thickness as the "Required Thk. for Nozzle Cut "

$$tv1 := \left(\frac{Mh1\cdot 6}{Lv1\cdot Sa}\right)^{0.5}$$ $tv1 = 0.921\ in$

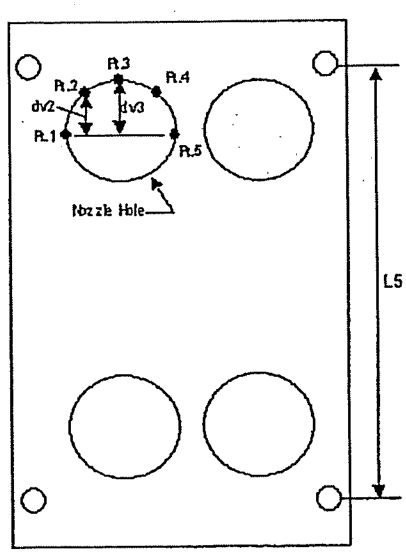
$$dv2 := \left[(2\cdot d3)^2 - (d3)^2\right]^{0.5}$$ $dv2 = 3.763\ in$

$Lv2 := (L5 + Db) - 4\cdot dv2$ $\quad Lv2 = 46.698\ in$

$$tv2 := \left(\frac{Mh2\cdot 6}{Lv2\cdot Sa}\right)^{0.5}$$ $tv2 = 1.568\ in$

$dv3 := 2\cdot d3$ $\quad dv3 = 4.345\ in$

$Lv3 := (L5 + Db) - 4\cdot dv3$ $\quad Lv3 = 44.370\ in$



(Fig.6)

$$tv3 := \left(\frac{Mh3 \cdot 6}{Lv3 \cdot Sa}\right)^{0.5} \qquad tv3 = 1.923\,in$$

$Lv4 := Lv2$

$$tv4 := \left(\frac{Mh4 \cdot 6}{Lv4 \cdot Sa}\right)^{0.5} \qquad tv4 = 2.071\,in$$

$Lv5 := Lv1$

$$tv5 := \left(\frac{Mh5 \cdot 6}{Lv5 \cdot Sa}\right)^{0.5} \qquad tv5 = 1.902\,in$$

From above it can be noted that Mh4 along with Lv4 is producing the highest thickness requirement . We will use this combination in the calculations below.

(6) FRAME THICKNESS FOR NOZZLE REINFORCEMENT

TAKING THE VECTOR SUM OF Mv+Mh , WHERE Mv & Mh ARE HIGHEST OF MOMENTS AT 5 POINTS. THIS WILL DETERMINE THE MAXIMUM STRESS IN THE NOZZLE CUT-OUT AREA & MINIMUM THICKNESS REQUIRED AT THE NOZZLE HOLE , IN COMPENSATION OF NOZZLE HOLE CUTOUT.

$Maximum_{vert\_stress} := Mh4$

$Maximum_{horz\_stress} := M2 \qquad Maximum_{horz\_stress} = -89170.6816\,lbf \cdot in$

$L7 = 12.370\,in$ FRAME WIDTH SUBTRACTING NOZZLE HOLE CUT-OUTS

$$T_{reqd\_thk} := \left[\left(\frac{6}{Sa}\right) \cdot \left[\left(\frac{Maximum_{vert\_stress}}{Lv4}\right)^2 + \left[\left(\frac{Maximum_{horz\_stress}}{L7}\right)^2\right]\right]^{.5}\right]^{.5}$$

$T_{reqd\_thk} = 2.192\,in$

THE BEAM ANALYSIS PROCEDURE USED ABOVE SHOWS THAT THE FRAME WITH NO ADDITIONAL REINFORCEMENT AROUND THE NOZZLE CUT-OUT, WILL CARRY THE DESIGN LOAD WITHOUT EXCEEDING THE ALLOWABLE BENDING STRESSES.

(7) CHECK MOMENT AT NOZZLE CENTERLINE. (SEE FIG. 4 FOR DRAWING OF NOZZLE CUT-OUT AREA.)

$x := 6.19 \cdot in$ x= THE DISTANCE FROM SUPPORT NO. 1 TO CENTER OF NOZZLE.

$$Mh := F1 \cdot x - \left[\frac{1}{2} \cdot Wv \cdot (x - La)^2 \right] \qquad Mh = 62423.5654\, lbf \cdot in$$

SUMMARY:

$Tp = 2.0034\, in$ $Tb = 1.0438\, in$ $Db = 1.5000\, in$ BOLT DIAMETER

$T_{reqd\_thk} = 2.1915\, in$ NOZZLE REINFORCEMENT $T_{actual} := 2.50 in$

$CA := 0.125 \cdot in$ corrosion allowance on pressure containing carbon steel

Calculations are in accordance with:
ASME Section VIII Div. 1.
2004 edition
2004 latest addenda.
By: Claude Boles, 04-25-2005
Checked By: A.P. Mathur P.E., 04-25-2005

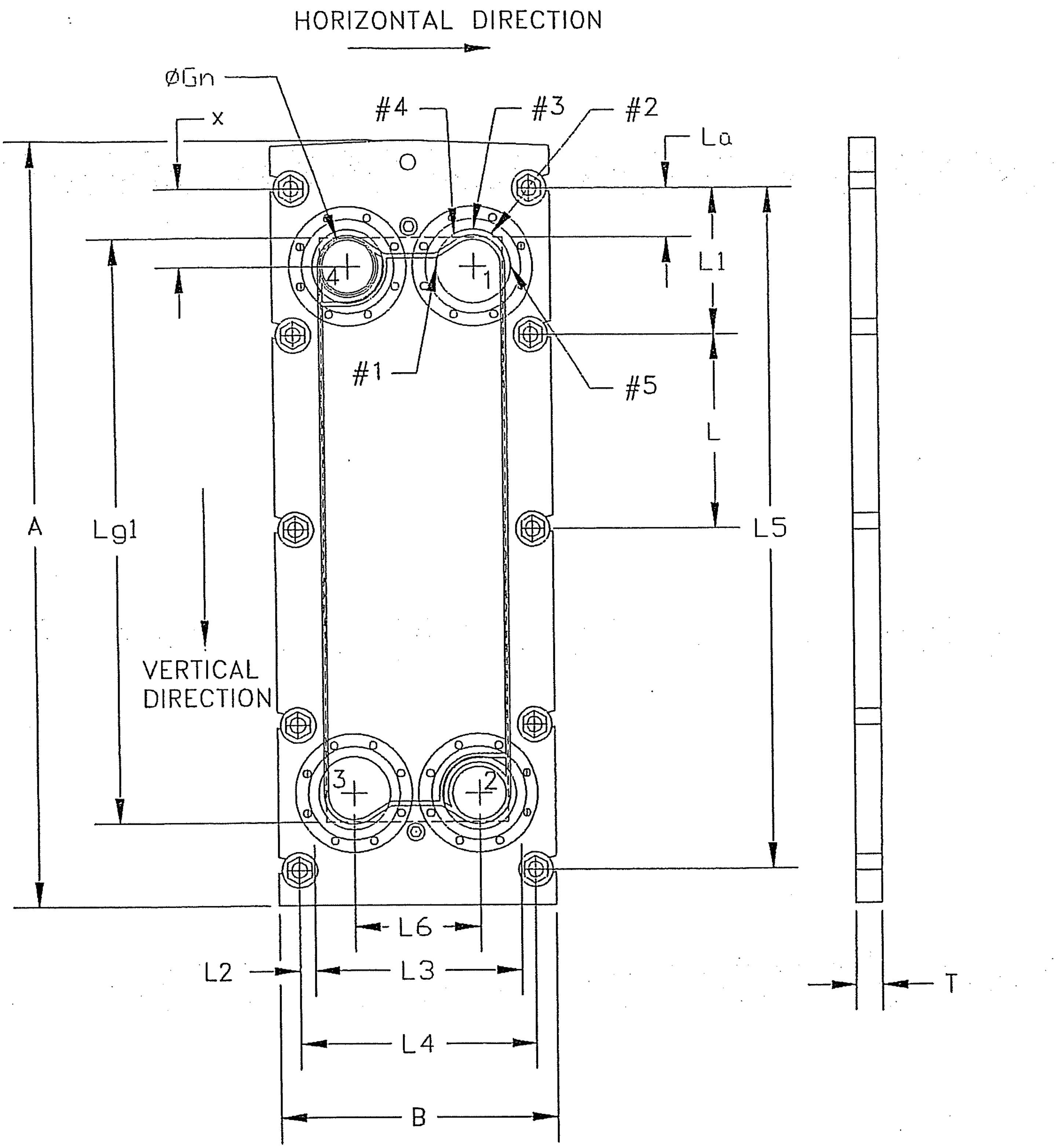
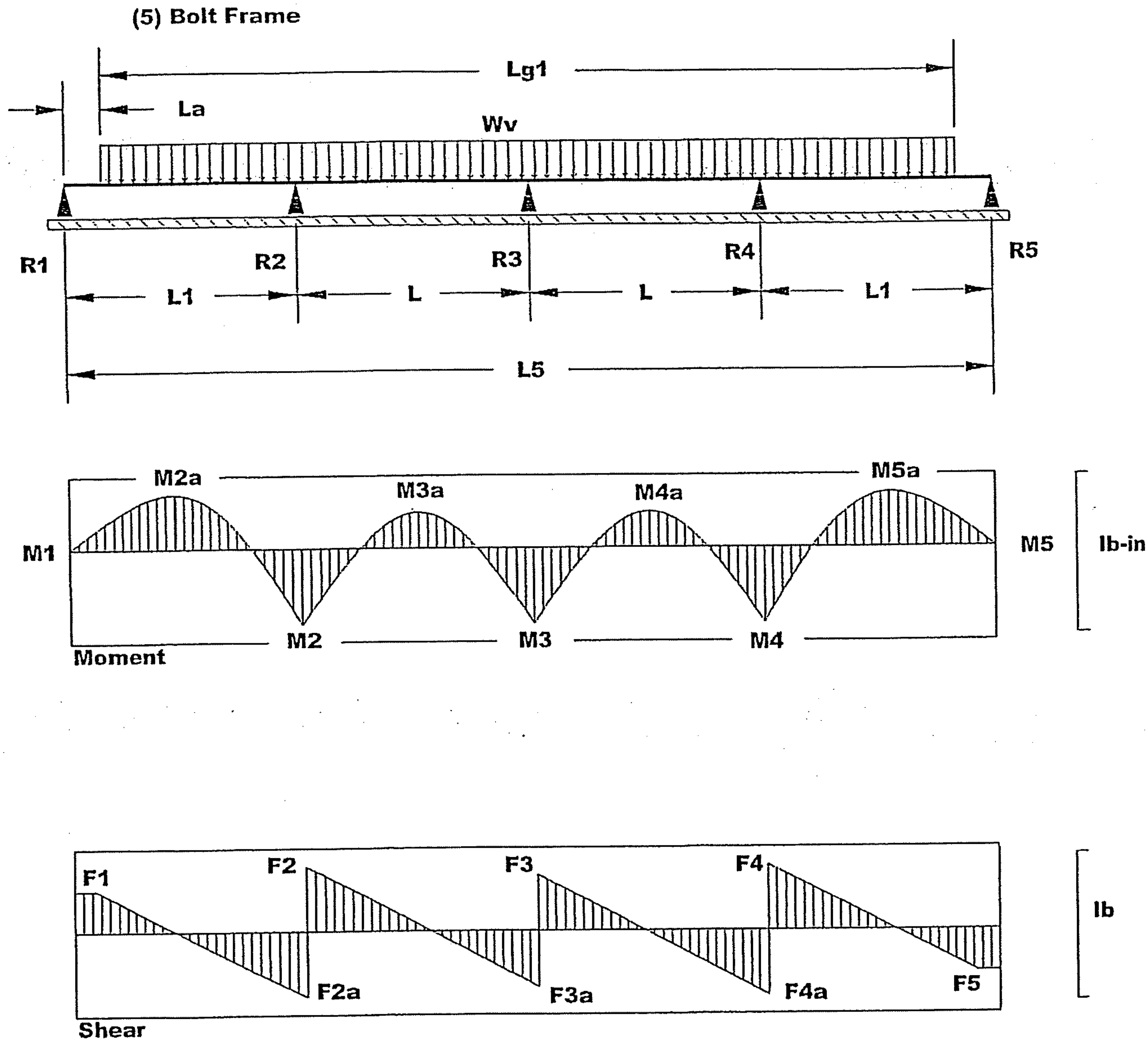

HORIZONTAL DIRECTION
ØGn
x
#4
#3
#2
La
L1
#1
#5
L
A
Lg1
L5
VERTICAL DIRECTION
4
1
3
2
L6
L2
L3
T
L4
B

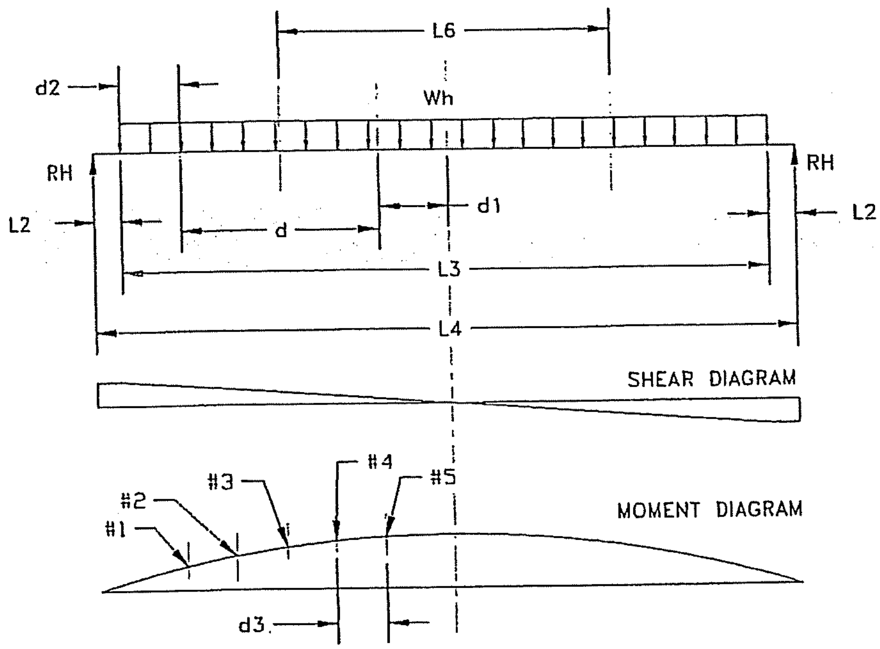
Figure 1

Figure 2



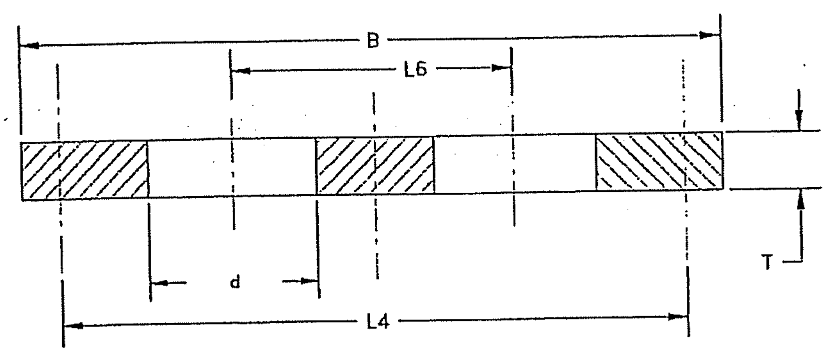
(5) Bolt Frame
Lg1
La
Wv
R1
R2
R3
R4
R5
L1
L
L
L1
L5
M2a
M3a
M4a
M5a
M1
M5
lb-in
M2
M3
M4
Moment
F1
F2
F3
F4
lb
F2a
F3a
F4a
F5
Shear

Figure 3



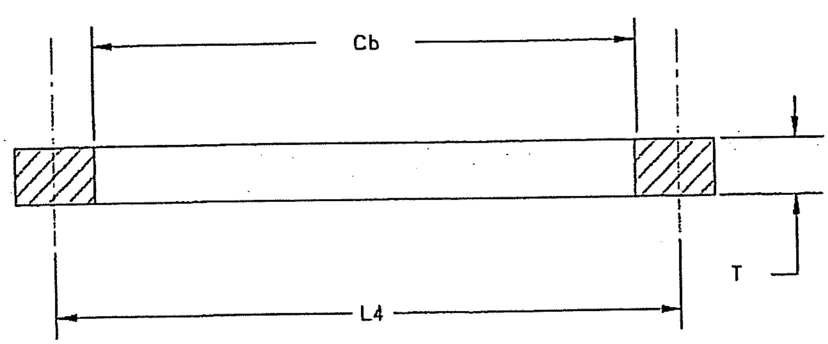
HORIZONTAL BENDING MOMENT DIAGRAM

Figure 4



NOZZLE CUT-OUT AREA

Figure 5



BOLT CUT-OUT AREA